Running head: *EARWORMS (STUCK SONGS)*

Earworms ("stuck song syndrome"): Towards a natural history of intrusive thoughts.

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Abstract

Two studies examine the experience of "earworms", unwanted catchy tunes that repeat. Survey data show that the experience is widespread but earworms are not generally considered problematic, although those who consider music to be important to them report earworms as longer, and harder to control, than those who consider music as less important. The tunes which produce these experiences vary considerably between individuals but are always familiar to those who experience them. A diary study confirms these findings and also indicates that, although earworm recurrence is relatively uncommon and unlikely to persist for longer than 24 hours, the length of both the earworm and the earworm experience frequently exceed standard estimates of auditory memory capacity. Active attempts to block or eliminate the earworm are less successful than passive acceptance, consistent with Wegner's (1994) theory of ironic mental control.

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Experimental research on unwanted cognitions covers many different types of intrusive thought ranging from the mundane (thought suppression experiments in which participants are asked to avoid thinking of a particular stimulus) to the pathological (auditory hallucinations, obsessive thoughts, post-traumatic "flashbacks"). Studies have investigated how intrusive thoughts recur and are controlled (e.g., Wegner, 1994), but it is difficult to apply experimental methodologies to the appearance of involuntary cognitions and such experiences might be better investigated using observation of everyday occurrences (Reason & Mycielska, 1982), a procedure recently advocated as "cognitive ethology" (Kingstone, Smilek & Eastwood, 2008) and one that has been championed by one of the founders of modern cognitive psychology (Neisser, 1976).

One apparently widely-experienced involuntary cognition is the "earworm", also referred to as "stuck song syndrome" (Levitin, 2006) "involuntary musical imagery" (INMIs; Liikkanen, 2008), "brainworms" or "sticky music" (Sacks, 2007). Simply, an earworm is the experience of an inability to dislodge a song and prevent it from repeating itself in one's head. Literary references to the phenomenon have been traced as far back as Mark Twain (1876). The virulent nature of the experience has resulted in catchy tunes being cited as possible candidates for memetic transmission and "infection" (Blackmore, 1999; Dawkins, 1976; Dennett, 1991). The phrase "earworm" is a direct translation of the German term *ohrwurm* which has recently gained widespread publicity via popular science books (e.g., Levitin, 2006; Sacks, 2007), and the internet. For example, a company producing "mobile brain trainers" as an electronic language-learning aid trades under the name (*www.earwormslearning.com/)*, the exploratorium science and arts museum of San Francisco displays an online exhibition

(*http://www.exploratorium.edu/music/questions/earworm.html*) and the University of Cincinatti hosts a website (*http://www.business.uc.edu/earworms)* devoted to the topic.

Despite the apparent prevalence of the earworm phenomenon, its long history, and the obvious popular interest in the topic, there has been a dearth of detailed scientific exploration. An introspective self-analysis of the subjective experience of musical imagery is reported by Brown (2006) and a factor analysis was carried out by Barŭss and Wammes (2009) in which involuntary musical imagery was found to be weakly related to personality factors and more strongly related to transliminality (a measure of cognitive penetrability). However, the references most commonly cited in the public media are to a series of unpublished studies by Kellaris (2001, 2003, 2006; these unpublished studies are also briefly reviewed in Kellaris, 2008, pp. 847-849) who refers to a "cognitive itch". The largest empirical investigation of the phenomenon to date is by Liikkanen (2008) surveying nearly12,000 Finnish internet users. Liikkanen found that INMIs were typically reported as occurring "everyday" (33.2% of the sample) with more than 90% of respondents indicating that they experience an INMI at least every week (Liikkanen, 2008, p. 409). Music was the most commonly occurring form of involuntary cognition and the one most frequently considered to be disturbing. Ratings of involuntary musical images as disturbing were (at 15.1%) more than twice as high as those of the next most disturbing stimulus (visual images at 7.4%). This potentially links the earworm phenomenon to the symptoms of Obsessive-Compulsive Disorder in that it hints at a distressing element to the involuntary imagery (DSM-IV; APA, 2005).

Published accounts of studies on musical imagery also provide a useful source of information relevant to earworms. Experience-sampling a group of music students

(Bailes, 2006, 2007) revealed high incidence of musical exposure over a seven-day period: 44% of the time students were hearing music when prompted to complete the form, 32% of the time they were imagining music and 21% both hearing and imagining music. As the participants were music students, this incidence is likely to be higher than in the general population, and the experience sampling does not explicitly target earworms but covers all forms of musical imagery. Nevertheless, this provides at least *prima facie* evidence for the prevalence of earworms and hence their legitimacy as the subject of psychological enquiry. It is also consistent with Liikkanen's (2008) data, showing an association between INMIs and musicality.

The brief review above represents, so far as we are aware, the sum total of peer-reviewed data on the earworm phenomenon to date. Lack of published data on the phenomenon has not prevented opinion and speculation appearing under the guise of accepted scientific fact, however. Levitin (2006) for example, whilst accepting that "there has been relatively little scientific work done on the topic" nevertheless goes on to report that "musicians are more likely to have earworm attacks than non-musicians, and that people with obsessive-compulsive disorder (OCD) are more likely to report being troubled by earworms – in some cases medications for OCD can minimize the effects" (Levitin, 2006, p. 155). Whilst the former claim seems to be borne out by Liikkanen's subsequent (2008) study, the latter is not formally addressed in the scientific literature. Levitin also offers as an explanation for earworms that "the neural circuits representing the song get stuck in 'playback mode'" (Levitin, 2006, p. 155) this is consistent with recent neuroimaging data on musical imagery (Kraemer, Macrae, Green, & Kelley, 2005), but does little more than restate the phenomenon in neural terms. Additionally, the brain areas that provide the irritation experienced in

the presence of an earworm, and the areas active in attempting to – in Kellaris' (2001) phrase – "scratch the cognitive itch" are unknown.

Statements like these appearing in popular science books currently lack the support of published scientific data (no references are given to relevant studies). The statement regarding OCD, for example, is consistent with the rating of music as the most disturbing involuntary cognition (Liikkanen, 2008). It is, however, contrary to clinical reports of OCD patients. Documented musical obsessions amongst such patients are rare (Stein, Fineberg & Harvey, 2001; Zungu-Dirwayi, Hugo, van Heerden & Stein, 1999) although musical hallucinations may occur if OCD is comorbid with either schizophrenia or social phobia (Hermesh et al., 2005). Further statements include the assertion that the length of the song which is stuck is typically less than the capacity of echoic memory (given as between 15 to 30 seconds; Levitin, 2006; an estimate which is debatable (Crowder & Morton, 1969; Nairne, 1988; Penney, 1989)), that simple songs, commercial jingles or the theme music for television shows seem to get stuck more often – or to affect more people – than complex pieces of music, that women suffer from more earworms than men, that the presence of lyrics is immaterial, that earworms usually include lyrics, that earworms are usually stereotyped and invariant in character and that they have "a certain life expectancy" (Sacks, 2007). All of these claims appear in one or more of Levitin (2006) or Sacks (2007) or are reported by either or both the University of Cincinatti or San Francisco Exploratorium websites as based on unpublished studies by Kellaris (2001, 2003, 2006).

Other statements appear less didactic and more speculative. Sacks (2007), for example, suggests a continuum between the normal and the pathological (including repetition of movements or sounds in Tourette's syndrome and the involuntary

behaviours associated with frontal lobe damage as well as OCD), with "sudden, full-blown" earworms tending towards the pathological end of the spectrum. Some of these speculations are worth considering. Notwithstanding the lack of documented cases of earworms amongst OCD patients, the presumed relationship between earworms and OCD is given credence by evidence for failures of attentional inhibition in OCD (Muller & Roberts, 2005). Similarly, the suggestion that earworms are more prevalent now than in Twain's day because of the ready availability – and intrusiveness – of music in everyday experience is consistent with musical imagery studies (Bailes, 2006, 2007; Brown, 2006)

It would be precipitate to run a full experimental study on the earworm phenomena since there is no clear theoretical framework in which to base such a study, and it is incumbent upon us to establish either the prevalence or importance of earworms to mental life before attempting to build such a framework (Neisser, 1976). Accordingly, in what follows, we report an initial investigation of earworms using questionnaire and diary study self-report methods in order to provide the basic data to support a theoretical framework. Since a number of claims have been made linking earworms to OCD, the following questionnaire study both examines the prevalence of earworms and the extent to which they are experienced as intrusive or problematic. OCD is conceptualised as a problem managing intrusive thoughts, but such thoughts only lead to OCD if they are distressing or interfering and whilst, by definition, the earworm is difficult to manage it is unclear whether the irritation occasioned by an earworm ever results in interference or distress. The survey is designed to examine the earworm in its natural habitat – in everyday experience – and as such differs from studies of other unwanted zoological thoughts such as white bears (Wegner, 1994) or pink elephants (Navon, 1994) which have primarily been examined in the captivity of

an experimental laboratory. It will also address some of the claims that have previously been made about earworms in the popular science literature, examining the extent to which these claims have any basis in fact.

Study 1: Questionnaire Study

Method.

Participants. An opportunity sample of 103 participants (64 male, 39 female), aged 15-57 (mean=26.24, s.d.=10.46) were recruited from amongst visitors to University Open Days and members of the public waiting at Reading railway station or visiting Forbury Gardens (a popular town-centre park) between 12-2pm on a weekday in August, 2006.

Materials and design. Questions (Appendix A) were intended to capture a number of dimensions to the earworm experience. Question 1 queried the interference level of earworms, the extent to which they disrupt normal functioning, and questions 2 and 9 queried emotional response. Questions 3, 4 and 11 were intended to record the form that earworms take, questions 5 and 10 assessed duration and frequency of earworms and questions 6-8 assessed the respondents' opinions of what caused the earworms and whether they found them easy to dismiss. Age, gender and musical experience were also recorded.

Results.

Demographic associations. All of the respondents recognised the "catchy tune" or earworm phenomenon. They reported that earworms lasted for a significant period, with the majority (88.2%) reporting tunes lasting over a period of hours or even longer. For formal analyses, likelihood ratios are predominantly reported here because

reported importance (yes/no) is a categorical variable but other variables (e.g., duration) are ordinal. Chi-square was not appropriate because there were too many zero cells. Fifty-five participants (33 male, 22 female) reported previous musical training, but there were no significant associations between musical experience and any other variables, although there were positive relationships between the reported importance respondents ascribed to music (as recorded by participants' yes/no responses to this question) and both the reported duration of the tunes (measured by Question 5; likelihood ratio (8)=18.42, p =.018) and how troubling the tunes were considered to be (Question 2; likelihood ratio (8)=23.62, p =.003). That is, those who considered music important were more likely to report tunes lasting longer, and to report experiencing them as more troubling. A negative association between the importance of music and the ease with which earworms are controlled (measured by Question 8) just failed to reach significance, likelihood ratio (6)=12.54, p =.051. In a test for differences between groups, Mann-Whitney U test failed to find any difference in reported frequency of earworms between males and females, z =-.437, p =.662, inconsistent with Liikkanen (2008).

Parts of the song experienced. Respondents reported that if one part of the tune is experienced it is typically the chorus or refrain, (38.8% of the participants surveyed), but it is also likely to vary (45.6%). There was no significant relationship between the level of interference (measured by Question 1) and whether lyric, melody or both are experienced (measured by Question 3; likelihood ratio (8) = 11.82, p =.159).

Interference effects. For most respondents the earworms were not considered actively problematic but some respondents reported that earworms stopped them doing other

things and wasted some (4.5%), or lots of time (5.5%). There was a trend towards an association between age and the interference measure, Kendall's τ =-0.13, p =.087, (interference is not normally distributed so a non-parametric correlation, Kendall's tau, is reported here) and a significant association between the interference measure and the importance respondents ascribed to music, likelihood ratio (8) = 23.63, p =.003 similar to the relationships between importance and other factors reported above.

There was a significant positive relationship between how worrying (Question 6b) and unpleasant (Question 9) an earworm was considered to be, r =.253, p <.05 but no relationship between the duration of the earworms and the extent to which they interfered with normal functioning, τ =.02, p =.83. There was a significant positive correlation between interference and controllability (Question 8) of earworms, however, τ =.28, p <.001 and an association between interference and the frequency (Question 10) of earworms, τ =-.232, p=.004, with participants reporting less frequent earworms also reporting greater interference from the earworms they experienced. There were no relationships between the duration of the earworms and their frequency, or how easy they were to control, nor between the controllability and frequency of earworms (p>.05 in all cases).

Open-ended questions. The modal response to question 11 (whether catchy tunes that got "stuck" were always the same tune) was that each occasion was a different tune (47.3% of responses compared to 32.7% and 10.9% for the same few tunes and always the same tune respectively). Participants were also asked to give examples of tunes that they found difficult to dismiss. 159 such songs were named, including 11 TV/film themes and 12 advertising jingles. In addition, there was one mention of

"adverts generally", one of video-game tunes, two mentions of children's music and one of Christmas songs. The remainder were exclusively pop music. Fourteen artists were mentioned by name with no song given. There was very little repetition within the list although, within artists, this sample mentioned Pink Floyd three times, Guns 'n' Roses four times and Justin Timberlake five times. Ten other artists were similarly represented more than once, but no more than 2-3 times each. The activities participants employed to rid themselves of earworms were classified under one of five headings, given in Table 1.

TABLE ONE ABOUT HERE

Discussion.

The results of this study clarify some features of the earworm experience. Notwithstanding Liikkanen's (2008) report that intrusive musical imagery is the most disturbing of involuntary cognitions, we found little evidence that respondents considered their earworms actively problematic. Likewise we did not replicate Liikkanen's (2008) report of a sex difference in the incidence of earworms, although this could simply be the result of a lack of statistical power in this survey (n = 103, 38% female) compared to Liikkanen's internet study (n = 11, 904, 68% female) given the small effect size in Likkanen's study (η_p^2 =.0133).

Those who found the earworms most problematic were respondents who considered music particularly important, these participants also reported experiencing earworm-episodes of longer duration and harder to control than participants for whom music was of less importance. These results confirm previous speculation regarding a relationship between musicality and earworm experience, although they emphasize

the subjective importance of music rather than musical skill or experience, contrary to Levitin's (2006) suggestion that earworms are more prevalent amongst musicians per se, which confounds musical skill and experience with the importance ascribed to music. The results are also consistent with the idea that involuntary cognitions that are viewed as important are more likely to be problematic than those with neutral or personally unimportant content. To this extent the earworms seem to behave like pathological intrusive thoughts, which only become so if their content is viewed as sufficiently unpleasant or distressing. Additionally, participants who experience earworms less frequently, or consider them less controllable, also report them as more problematic.

The extent to which an earworm is considered worrying is also related to its unpleasantness rating, although there was no effect of unpleasantness on the earworm episode's duration, implying that more worrying and unpleasant earworms differ from pathologically obsessive thoughts (contrary to suggestions by Levitin, 2006) in being relatively short-lived and, in a nonclinical population at least, do not attract obsessive thoughts are not considered particularly problematic or even intrusive (beyond the annoyance often associated with such experiences). This is consistent with Sacks' (2007) assumption that earworms have a certain (undetermined) "life-expectancy" which, presumably, is rarely prolonged to any great degree. Although the current data do not allow us to estimate this life-expectancy with any degree of precision, the modal reported duration of an earworm episode as over a period of hours is inconsistent with Levitin's (2006) claim that earworms are limited by the capacity of auditory memory, however it is possible that a distinction needs to be drawn here between the period of time over which an earworm manifests itself (an earworm-episode) and the length of the tune constituting the earworm. Given that the

majority of reported earworms were popular music tunes, it is unlikely that an earworm-tune could consistent of a musical piece longer than approximately three minutes.

Interestingly, the earworms reported were always familiar to the participants, no reports were given of unknown or novel tunes acting as earworms although this may be a consequence of the way in which the question was phrased ("Please list below any tunes that you can remember getting stuck in your head on previous occasions"), which may have encouraged participants to write down only "known" tunes. The incidence of TV/film themes or advertising jingles was also not particularly high, contrary to previous suggestions (Kellaris, 2008) and the tunes also seem to be virtually unique to each individual, suggesting that lists of the most potent earworms (e.g., Kellaris, 2001) are misleading. The earworms varied with regard to which part of the song was involved, but the chorus was most frequently cited.

Study 2: Diary Study.

Although the questionnaire study provides data which takes us beyond the previous purely speculative comments regarding earworms (Kellaris, 2008; Levitin, 2006; Sacks, 2007), a limitation on the current conclusions is that the reports of Study 1 are retrospective and hence, like other surveys of earworm experience (e.g., Liikkanen, 2008), subject to potential recollection bias. Additionally, the results of this study are averaged over a large number of individuals each recording their assessment of numerous earworm episodes with no possibility of examining individual earworms in-depth or determining which of the activities listed in Table 1 are effective at dismissing earworms.

To address these limitations, Study 2 examines individual earworm episodes, with participants recording their incidence, and their own response, as they occur. The advantages and shortcomings of both survey and diary data are discussed in-depth by Reason and Mycielska (1982), particularly with regard to their study of mental lapses and everyday errors. Like everyday errors, it seems most appropriate to study "everyday" earworms using both these techniques as they are to a certain extent complementary and more objective methods present difficulties given the infrequent and involuntary nature of the subject matter (see Reason & Mycielska, 1982, pp. 21-23 for a discussion; Kingstone et al., 2008, and accompanying commentaries provide a more recent outline of the advantages, constraints and criticisms of this and other forms of "cognitive ethology").

Method.

Participants. Twenty-five individuals (10 male, 15 female) responded to an online advertisement posted in September 2006 and volunteered to participate. Of these, twelve (3 male, 9 female) submitted diary reports of their earworm experiences. Nine were undergraduate students, one was a postgraduate and two were non-students. One participant identified herself as a musician with over five years experience. None had participated in Study 1.

Materials & Design. Participants were given a standardized set of instructions explaining the nature of earworms and of the diary. They were sent a standardized form (Appendix B) and requested to submit (i.e., return by post) completed diaries at fortnightly intervals, that is after two and four weeks.

Results.

A total of 269 earworm episodes were recorded, averaging 1.12 episodes per week (range = 0.25-2.5). The earworms were associated with 199 different tunes. Of the 70 tunes which appeared more than once only 10 were reported as earworms by more than one individual, consistent with Study 1's result showing little repetition of earworms either within or between individuals. The frequency of children's songs (3), TV/radio themes (9) and advertising jingles (7) was broadly equivalent to that previously observed and, additionally, a small number of non-pop tunes were reported, including two folk tunes, one jazz instrumental and four show tunes. 33% of the earworm episodes were reported as consisting of the chorus only, consistent with Study 1, 27% were reported as fragments (e.g., "end bit only", "small section", "just one line") likely to be shorter than the chorus and a surprising 28% of episodes reported involved the entire song. The average duration of an earworm episode, 27.25 minutes, was substantially shorter than suggested by Study 1.

The modal assessment of the earworm interference was that they did not interfere nor waste time (66% of the time), although the percentage of occasions in which they were judged to interfere a little but not waste time (10%), interfere a little and waste time (9%), interfere and waste some time (4%) or interfere and waste a lot of time (1%) were higher than those previously reported. Only 89 earworm episodes (33.1%) were reported as unpleasant (scores of *a*-*d* on the rating scale (86 episodes), or a score of *f* with a verbal statement consistent with a negative experience (3 episodes)). The majority (50.6%) were reported as pleasant (136 scores of *e* and 7 scores of *f* together with a positive verbal statement), the remainder being ungraded (31 episodes) or neutral (6 episodes). Of recurring earworms, only 25.56% were recorded as unpleasant. Figure 1 shows the number of times each earworm recurred and the recurrence rate of an earworm within seven days of its first appearance.

FIGURE ONE ABOUT HERE

Activities reported to try and remove earworms were categorized as in Table 1. In this sample, no active attempt to remove an unwanted earworm was made on 56% of occasions, earworm elaboration only occurred on 4% of occasions, specific displacement activities were attempted 21% of the time and generalized distraction techniques 12%. Figure 2 shows the effectiveness of three of these strategies (nothing, specific displacement and generalized distraction). Earworm elaboration is not included because the small numbers of episodes involved render this data-point unreliable although, numerically, this condition resulted in the longest earworm activity (47 minutes).

FIGURE TWO ABOUT HERE

A by-participant analysis of variance (ANOVA) was not possible because of the small numbers involved, the extent of intra-participant variability and its interaction with inter-participant variability. For example, not all participants varied in their report of distraction activities intended to displace the earworm and some participants reported multiple different types of distraction activity (hence distraction activity would qualify as both a within- and between-participant factor in such an analysis). However, a by-item analysis (Fisher, 1935) with distraction activity and participant as fixed factors and each individual earworm episode constituting an observation, found no main effect of activity, $F<1$, but a significant main effect of participant $F(11,192) = 10.03$, $p < .001$, $\eta_p^2 = .365$ and an activity by participant

interaction, $F(12,192) = 2.02$, $p = .024$, $\eta_p^2 = .112$. The absence of a main effect is explained by missing data-points for some participants, not all of whom reported attempting distracter activities. Since only three means are involved, it is possible to run post hoc analyses on this interaction without affecting the family-wise error rate (see Howell, 2007). Post hoc Fisher's LSD showed significant differences between no activity and both specific and generalized distraction, $p = .032$ and $p = .048$, respectively, but no differences between specific and generalized distraction activities, $p = .884$.

Discussion.

The diary study largely confirms the findings of the questionnaire concerning both the frequency and individuality of earworms. Earworms are both frequent (although slightly less so in the diary study than in the questionnaire) and idiosyncratic, with little overlap between individuals and little recurrence (at least over the short-term) within individuals. As before, although popular tunes predominated, there was no evidence that simple songs such as children's songs, jingles or theme tunes were over-represented in the earworms reported. The length of the earworm is frequently longer than the relatively short duration of auditory memory, with whole songs sometimes being experienced. This fact can be explained by the finding that participants in this study could name 99% of the earworms they reported. Hence, consistent with Study 1, the earworm is a familiar tune and presumably involves not just auditory memory but the reactivation of long-term memory representations.

The diary study also provides the first opportunity to consider cognitive control strategies related to earworms. The most obvious theoretical framework to

apply is Wegner's (1989, 1994) theory of ironic mental control. This theory suggests that the need to consciously monitor a mental control process to determine its success is self-defeating when the goal of the control process is to remove an item from conscious awareness as the representation of this goal necessarily reinstates the item in consciousness whenever the monitoring process is deployed. Hence, according to this theory, any conscious attempt to displace or remove an earworm is unlikely to succeed as monitoring this attempt simply re-presents the earworm to the individual. The results of the by-item analysis are consistent with this idea, showing longer earworm-episodes when specific attempts are made to displace them. However, these results are equally consistent with the possibility that only particularly virulent (in some sense) earworms attracted this kind of activity and future experimental studies, with more control over the situation and running by-participant analyses, are necessary to confirm these results and decide between these two possible interpretations.

General Discussion.

With regard to the comments made about earworms in popular science sources, a number of claims were identified earlier. These were that musicians are more likely to suffer from earworms than non-musicians, that OCD patients were more likely to report earworms (and that medication for OCD can result in the disappearance of such earworms), that the length of the song which is stuck is typically less than the capacity of echoic memory (given as between 15 to 30 seconds; Levitin, 2006), that simple songs, commercial jingles or the theme music for television shows seem to get stuck more often – or to affect more people – than complex pieces of music (Kellaris, 2001, 2003), that women suffer from more

earworms than men, that the presence of lyrics is immaterial, that earworms usually include lyrics, that earworms are usually stereotyped and invariant in character and that they have a certain "life expectancy" (Sacks, 2007). Whilst we are not in a position to decisively refute or confirm all of these claims, nevertheless the current study has provided sufficient data to address some of these suggestions and, in some cases, to provide potential alternative interpretations of some of these claims and to point the way for future research.

Firstly, whether musicians are more likely to suffer from earworms than non-musicians. Study 1 found no evidence for this, although this study sampled visitors to the Department of Psychology and other members of the general public, it did not specifically target professional musicians so it is unclear what results would be obtained if a specific comparison was carried out between experienced musicians and those with no musical training. The study did find positive relationships between the importance participants ascribed to music and a number of different dimensions of the earworm experience, however (including the reported duration of the earworm episode, how troubling it was considered to be, and how much the earworm interfered with other activities). These results suggest that receptiveness to music, rather than musical skill or experience, might be the appropriate dimension along which to look for musician-nonmusician differences. The current study also failed to find any sex difference, in contrast to Likkanen (2008), which we have interpreted as the result of a lack of statistical power to reveal a small effect size. Since gender could plausibly interact with emotional reaction to music, any future demographic study needs to take both these factors into account.

Secondly, the supposed link between earworms and OCD. We do not have formal data enabling us to examine the incidence of earworms amongst OCD patients

alongside that of comparable individuals in the general population so we have no definitive confirmation or refutation of this link. Nevertheless, the data we have are suggestive. Unexpectedly, many earworm episodes were not considered unpleasant at the time they were experienced (Study 2). Thus the content of the earworm is very different from that of a pathologically obsessive thought which, by definition, is distressing. Earworms ordinarily induce far less anxiety (Study 1). It is also noticeable that, unlike an obsessive thought, a particular earworm episode was unlikely to appear more than once in a single day and was usually gone completely by the next day (Study 2). When steps were taken to try and remove the earworm these proved counterproductive in terms of the episode duration. Thus, although ironic processes of mental control (Wegner, 1994) may be invoked when attempting to rid oneself of an earworm, the varied nature of the emotional reaction, the familiarity of the earworm and its lack of recurrence over time all suggest that the earworm as a phenomenon may be linked to obsessive thought disorders less by common origins in the generation of the intrusive thought than by use of common strategies to control the episode. We suggest, therefore, that (unnamed) medications for OCD (the majority of which are antidepressants which impact upon the emotional reaction to obsessive thought), are unlikely to have the beneficial effect upon the appearance and recurrence of earworms claimed by Levitin (2006). Two reported cases in which a patient presented with distressing musical pseudo-hallucinations (Praharaj et al., 2009) or obsessions (Zungu-Dirwayi et al., 1999) proved resistant to psychopharmacological treatment. This remains an avenue for future research.

Thirdly, the length and nature of the earworm. It is unclear what the 15-30 second echoic memory limit provided by Levitin (2006) is based upon. The limit of the classical precategorical acoustic store (Crowder & Morton, 1969) is considerably

less than this (decaying after 2-3 seconds, and with a capacity of only one item). The longer time-frame may refer to the acoustic code which Penney (1989) suggested aided memory in free recall and which she hypothesized as capable of retaining five items and lasting, in the absence of attention, for 20-60 seconds. A further possibility is the supposed 1.5-2s time limit of the "phonological store" although this is generally taken to refer to speech sounds only, and requires active rehearsal to hold in memory (although see Baddeley, 2000, for evidence on the insufficiency of this concept). All four estimates are considerably below the reported duration of an earworm episode as lasting approximately 27 minutes (study 2) or several hours (study 1), although a possible distinction between the length of an earworm-episode and an earworm-tune might account for this discrepancy. Such a distinction does not account for the report, by some participants, of whole songs (of presumably several minutes duration) appearing as earworms but the observation that in both studies only familiar songs are reported as earworms complicates the issue by implicating long-term memory in the appearance of earworms. Participants in Study 1 may have been responding to the wording of the question (which implicitly assumed that the earworm was already known) when reporting only familiar tunes as earworms but the finding was replicated in Study 2 when participants were explicitly asked "Can you name the earworm?"

The tunes which participants reported as earworms also varied considerably. Since all were known to the participants, it seems that familiarity with a tune is prerequisite for it to form an earworm (a related observation has also been made regarding musical hallucinations; Warner & Aziz, 2005), prompting the suggestion that only overlearned tunes are available to be "replayed" as earworms. Simple and repetitive tunes are more likely to become overlearned over a short time period, consistent with Kellaris (2001), but exposure to the tune is the critical factor rather

than the characteristics of the tune per se, suggesting that differential musical exposure would result in different patterns of earworms. This idea is supported by the observation that although popular, and predominantly recent, music tunes (likely to be overlearned) were by far the most frequent earworms reported in the current study there was very little evidence for overlap in earworms across participants (Study 1) or even within the same participant over time (Study 2). These results do not support the idea that certain tunes are intrinsically more likely to become earworms than others but do suggest that popular or otherwise very familiar tunes interact with some other, unknown but idiosyncratic factor, to form earworms.

References

American Psychiatric Association (2005). *Diagnostic and statistical manual of mental disorder* (5th ed.). Washington, DC: Author.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4,* 417-423.

Bailes, F. A. (2006). The use of experience-sampling methods to monitor musical imagery in everyday life. *Musicae Scientae, 10,* 173-190.

Bailes, F. A. (2007). The prevalence and nature of imagined music in the everyday lives of music students. *Psychology of Music, 35,* 555-570.

Barŭss, I. & Wammes, M. (2009). Characteristics of spontaneous musical imagery, *Journal of Consciousness Studies, 16,* 37-61.

Blackmore, S. (1999). *The meme machine*. Oxford: Oxford University Press.

Brown, S. (2006). The perpetual music track: The phenomenon of constant musical imagery. *Journal of Consciousness Studies, 13,* 25-44.

Crowder, R. G., & Morton, J. (1969). Precategorical acoustic storage (PAS). *Perception & Psychophysics, 5,* 365-373.

Dawkins, R. (1976). *The selfish gene*. Oxford: Oxford University Press.

Dennett, D. C. (1991). *Consciousness explained*. London: Penguin.

Fisher, R. A. (1935). *The design of experiments*. Edinburgh: Oliver & Boyd.

Hermesh, H., Konas, S., Shiloh, R., Dar, R., Marom, S., Weizman, A., & Gross-Isseroff, R. (2004). Musical hallucinations: Prevalence in psychotic and nonpsychotic outpatients. *Journal of Clinical Psychiatry, 65,* 191-7.

Howell, D. C. (2007). *Statistical methods for psychology* (7th edition). Belmont, Ca.: Wadsworth.

Kellaris, J. J. (2001). Identifying properties of tunes that get 'stuck in your head': Toward a theory of cognitive itch. In S E. Heckler & S. Shapiro, (ed.s), *Proceedings of the Society for Consumer Psychology Winter 2001 Conference*, Scottsdale, AZ, American Psychological Society, pp. 66-67.

Kellaris, J. J. (2003). Dissecting earworms: Further evidence on the 'song-stuck-in-your-head' phenomenon. In C. Page & S. Posavac, (ed.s,) *Proceedings of the Society for Consumer Psychology Winter 2003 Conference*, New Orleans, LA, American Psychological Society, 220-222

Kellaris, J. J. (2006). *Earworms, cognitive itch and ironic processes: An examination of the 'song stuck in the head' phenomenon*. Unpublished manuscript.

Kellaris, J. J. (2008). Music and consumers. In: C. P. Haugtvedt, P. Herr, & F. R. Kardes (Ed.s). *Handbook of consumer psychology*. New York: Taylor & Francis. pp. 837-856.

Kingstone, A., Smilek, D., & Eastwood, J. D. (2008). Cognitive ethology: A new approach for studying human cognition. *British Journal of Psychology, 99*, 317-340.

Kraemer, D. J. M., Macrae, C. N., Green, A. E., & Kelley, W. M. (2005). Sound of silence activates auditory cortex. *Nature, 434*, 158.

Levitin, D. (2006). *This is your brain on music: Understanding a human obsession*. London: Atlantic.

Liikkanen, L. A. (2008). Music in everymind: Commonality of involuntary musical imagery. In: K. Miyazaki, Y. Hiraga, M. Adachi, Y. Nakajima & M. Tsuzaki (Ed.s) *Proceedings of the 10th international conference on music perception and cognition (ICMPC10)*. 408-412. Sapporo, Japan.

Muller, J., & Roberts, J. E. (2005). Memory and attention in obsessive-compulsive disorder: A review. *Journal of Anxiety Disorders, 19*, 1-28.

Nairne, J. S. (1988). A framework for interpreting recency effects in immediate serial recall. *Memory & Cognition, 16,* 343-352

Navon, D. (1981) The forest revisited: More on global precedence. *Psychological Research, 43,* 1-32

Navon, D. (1994) From pink elephants to psychosomatic disorders: Paradoxical effects in cognition. *PSYCOLOQUY 5 (36)* paradoxical-cognition.1.navon *http://www.cogsci.ecs.soton.ac.uk/cgi/psyc/newpsy?5.41*

Neisser, U. (1976). *Cognition and reality*. San Francisco: W. H. Freeman.

Penney, C. G. (1989). Modality effects and the structure of short-term verbal memory. *Memory and Cognition, 17,* 398 – 422

Praharaj, S. K., Goyal, N., Sarkar, S., Bagati, D., Sinha, P., & Sinha, V. K. (2009). Musical obsession or pseudohallucination: Electrophysiological standpoint. *Psychiatry and Clinical Neurosciences, 63,* 230-234.

Reason, J., & Mycielska, K. (1982). *Absent-minded? The psychology of mental lapses and everyday errors*. Englewood Cliffs, N. J.: Prentice Hall.

Sacks, O. (2007). *Musicophilia: Tales of music and the brain*. New York: Random House

Stein, D. J., Fineberg, N., & Harvey, B. (2001). Unusual symptoms of OCD. In: N. Fineberg, D. Marazziti, & D. Stein (Eds). *Obsessive Compulsive Disorder: A practical guide*. London: Taylor & Francis. pp. 37-50.

Twain, M. A. (1876). A literary nightmare. *The Atlantic Monthly, 37,* 167-170.

Warner, N., & Aziz, V. (2005). Hymns and arias: Musical hallucinations in older people in Wales. *International Journal of Geriatric Psychiatry, 20,* 658-660.

Wegner, D. M. (1989). *White bears and other unwanted thoughts*. New York: Viking.

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101,* 34-52.

Zungu-Dirwaye, B. A., Hugo, F., van Heerden, B. B., & Stein, D. J. (1999). Are musical obsessions a temporal lobe phenomenon? *Journal of Neuropsychiatry and Clinical Neurosciences, 11,* 398-400.

Activity (frequency):	**Percentage response**
Inactivity: Go to sleep (3) Nothing (15) Forget about it (1	18.10
Earworm elaboration: Listen to the song (5) Think of the name of the song (1) Think about the song (1) Sing the song (1)	7.62
Specific (musical) displacement: Think of a different song (15) Listen to a different song (27) Play music i.e. an instrument (1) Sing something else (6)	46.67
Generalized displacement: Stay busy/ get on with work (18) Talk about something else (1) Meditate (1) Talk to somebody (3) Think of something else (3) Read (1)	25.71
Other: Drink alcohol (2)	1.90

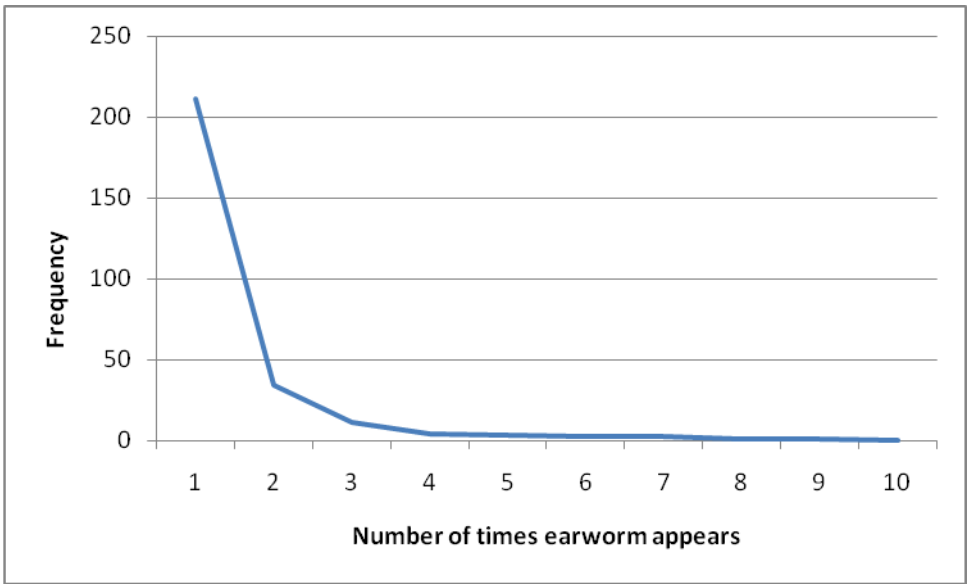
Table 1. Activities employed to remove earworms.

Figure Captions.

Figure 1: Frequency of earworm recurrence. The upper panel shows the frequency with which a tune recurred (1 refers to its first appearance). The lower panel shows the frequency as a function of time over a 7-day period. 1=same day recurrence, 2=next day and so on. Only earworms which recurred at least once are included in this panel.

Figure 2. Mean duration of an earworm episode as a function of distracter activity. Bars are standard error.

Figure One


250
200
150
100
50
0
Frequency
1
2
3
4
5
6
7
8
9
10
Number of times earworm appears

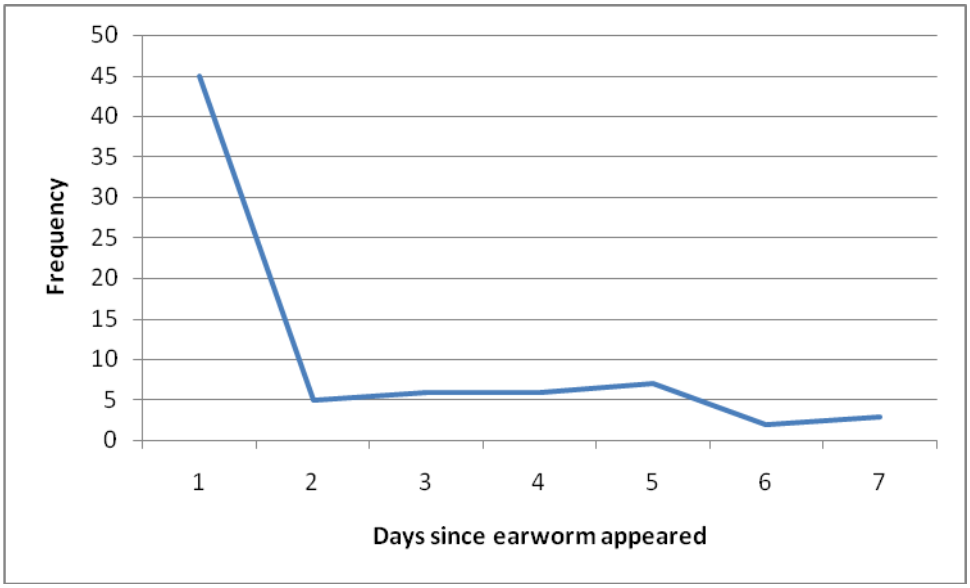
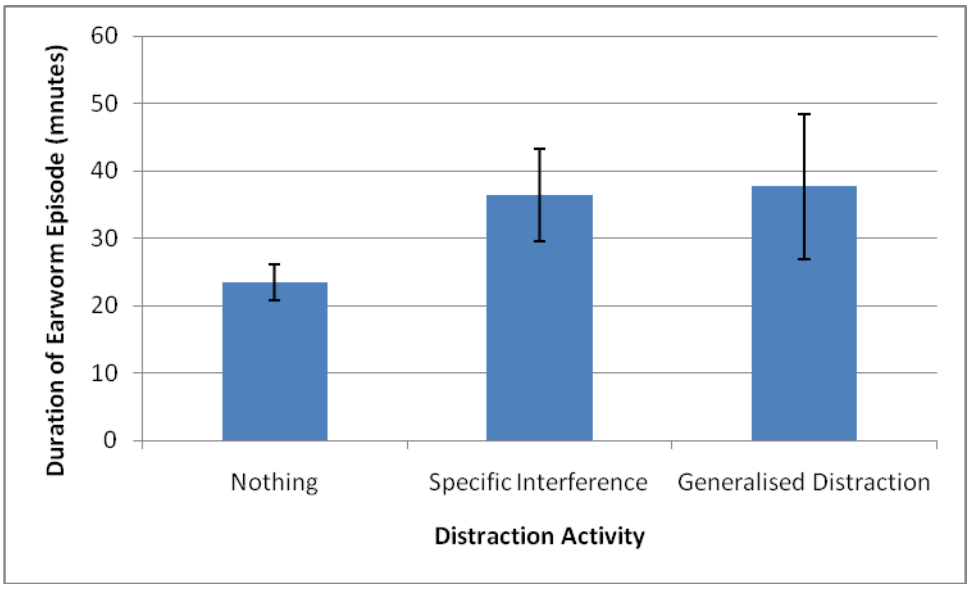

50
45
40
35
30
25
20
15
10
5
0
Frequency
1
2
3
4
5
6
7
Days since earworm appeared

Figure Two


Duration of Earworm Episode (mnutes)
60
50
40
30
20
10
0
Nothing
Specific Interference
Generalised Distraction
Distraction Activity

Appendix A: Questionnaire

Catchy Tunes Questionnaire

This is a questionnaire about catchy tunes: - the ones that get stuck in your head even though you do not want them to stay there. Not much is known about catchy tunes, so your answers will help us understand them a bit more.

Your age: ☐ Your gender: Male / Female

Do you currently, or have you previously played a musical instrument? No / Yes

If Yes: -Which instrument?…….. For how many years? …….

Please estimate how often you practise/ practised …….

Do you consider music to be an important part of your life? No / Yes

1. My catchy tunes

a. Never stop me doing other things I want to do and do not waste my time…… ☐
b. Stop me a little but do not waste my time…… ☐
c. Stop me a little and waste a little of my time…… ☐
d. Stop me from doing other things and waste some of my time…… ☐
e. Stop me from doing lots of things and waste lots of my time…… ☐

2. When a catchy tune is stuck I feel……..(tick all that apply)

a. Irritated…… ☐
b. Uncomfortable…… ☐
c. Sad…… ☐
d. Anxious…… ☐
e. Happy…… ☐
f. Other (please specify) …… ☐

3. The form a catchy tune usually takes is as:

a. Melody (tune only)…… ☐
b. Lyrics (words only)…… ☐
c. Melody and lyrics (tune and words)…… ☐

4. The part of the tune that gets stuck tends to be:

a. The opening few bars or lines…… ☐

b. The chorus or refrain……☐
c. The last few bars or lines……..☐
d. Somewhere in the middle of a verse……☐
e. It varies……☐

5. **How long can a catchy tune stay 'stuck' for**

a. Minutes……☐
b. Hours……☐
c. Days……☐
d. Weeks……☐
e. Months / longer……☐

6. Do you think anything you do makes catchy tunes get stuck

a. No……☐
b. Sometimes……☐
c. Yes……☐

(b). Does this worry you? (indicate your answer by marking the line)

Does not worry me at all Is extremely worrying

._____.

7. Do you know what triggers catchy tunes to get 'stuck'

a. No……☐
b. Yes (please specify)……☐

8. To get rid of catchy tunes is

a. Easy and takes no effort……☐
b. Easy but takes some effort……☐
c. Sometimes hard ……☐
d. Impossible……☐

9. A **catchy tune which is stuck is** (indicate your answer by marking the line)

Extremely pleasant Extremely unpleasant

._____.

10. On average I get catchy tunes in my head

a. At least once per hour……☐
b. At least once per day……..☐
c. At least once per week……☐
d. At least once per month……☐
e. Less often than once per month……☐

11. When a catchy tune is stuck in my head it is

a. Always the same tune…… ☐
b. The same few tunes…….. ☐
c. Different tunes each time …… ☐

Please list below any tunes that you can remember getting stuck in your head on previous occasions.

Please write down the lyrics of any catchy tune that has previously been stuck

Please list ways in which you try and rid yourself of catchy tunes when they are 'stuck'

Appendix B

Earworm Diary Study

Time (24hr) and day

Can you name the earworm? If so, what was it?

Where were you when the earworm appeared?

What was the MAIN thing you were doing when the earworm appeared (e.g., were you reading, working, listening to any music, and if so what?)

Who were you with, if anyone?

Please give a brief description of how complete the experience was, e.g., Was the music playing in your mind as a whole piece? Were you hearing a repeated fragment of it?

How long did the earworm persist?

Did you do anything to try and get rid of the earworm? If so, what?

Please also answer the following questions for EACH of the earworm episodes you describe:

Did the catchy tune:

a. Not stop you doing other things you wanted to do and not waste your time
b. Stop you a little but not waste your time
c. Stop you a little and waste a little of your time
d. Stop you from doing other things and waste some of your time
e. Stop you from doing lots of things and waste lots of your time

When you were experiencing the earworm, did you feel …..(tick all that apply)

a. Irritated
b. Uncomfortable
c. Sad
d. Anxious
e. Happy
f. Other (please specify)